DEVELOPMENT OF DIELECTRIC-BASED HIGH GRADIENT ACCELERATING STRUCTURES

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OUTLINE

1. The Recent High Power rf Testing of Quartz Based DLA Structure

2. Ways to Higher Gradient for DLA Structures

   - small I.D. quartz DLA structure design: Test high gradient and multipactor power scaling
   - Gapless DLA structure based on the new coupler design
   - Low loss double layer DLA structure

Part I

1. The Recent High Power rf Testing of Quartz Based DLA Structure
2. Ways to Higher Gradient for DLA Structures

   - small I.D. quartz DLA structure design: Test high gradient and multipactor power scaling
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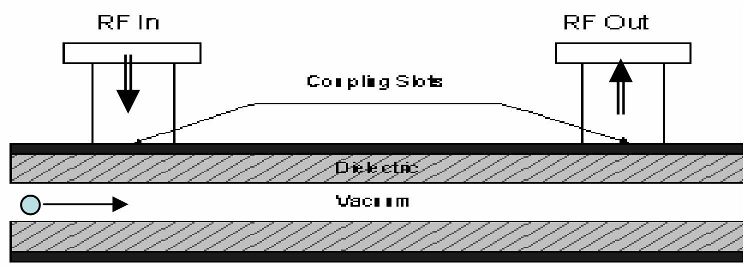
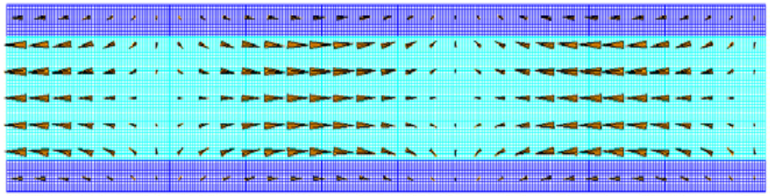
High Power RF Testing of The Quartz Based DLA Structure (I)

--------Introduction

•Dielectric-Loaded Accelerating (DLA) structure is a potentially candidate for the high gradient accelerator in the future.





•DLA Structure Development:

- •1) **Coupler Breakdown** (cured)
- •2) **Multipactor** (Anomalous Power Absorption)
- •3) **Joint Breakdown** at the dielectric gap.
- •4) **Tested Materials: MgCaTiO, Alumina, TiN coated Alumina**

•Motivation for Quartz Test: to test the multipactor effect of the different material due to quartz has relatively low secondary electron yield.

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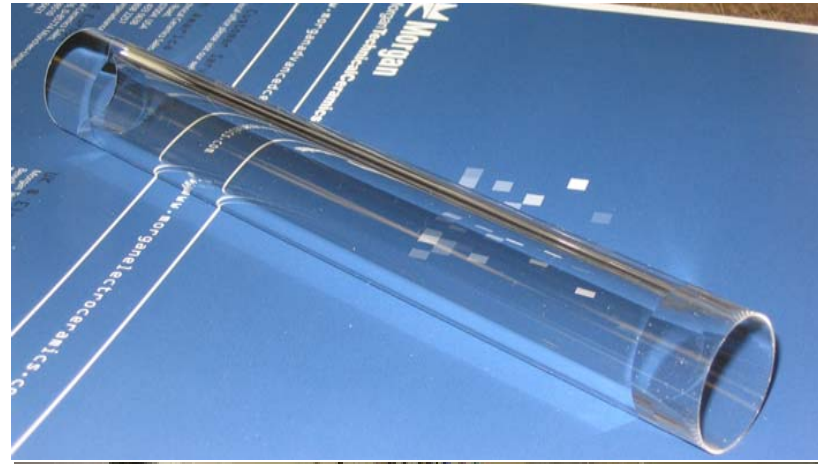
High Power RF Testing of The Quartz Based DLA Structure (II)

-------Design & Fabrication

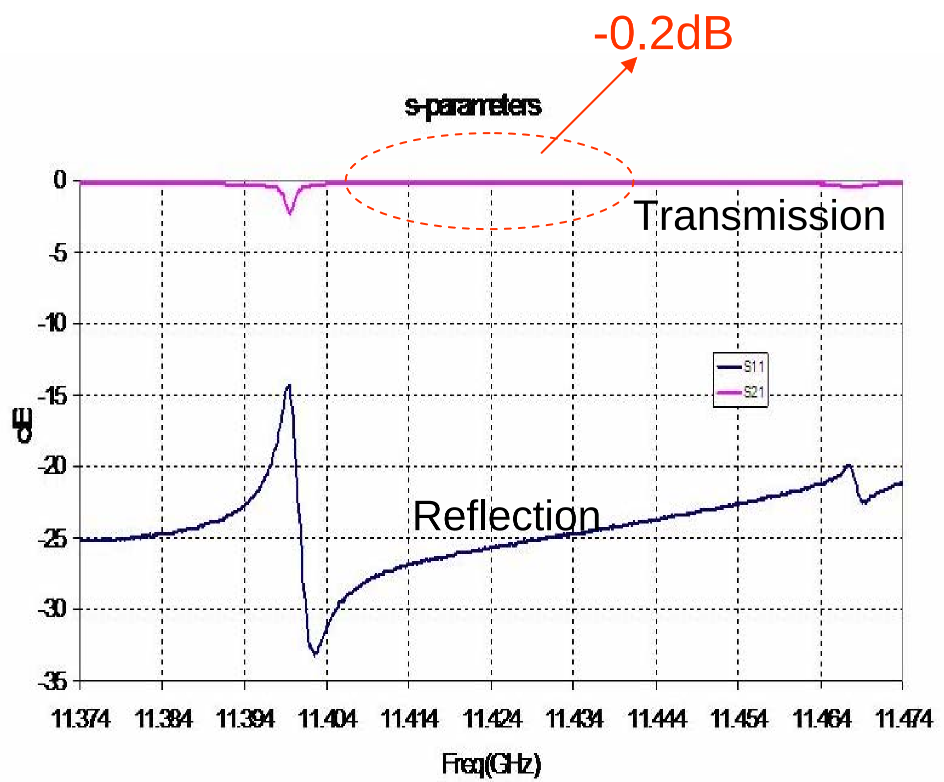
Parameters	Value
Material	Fused Silicon
Inner Radius	8.97mm
Outer Radius	12.08mm
Dielectric Const	3.78
Group Velocity	0.38c
R/Q	3.614kΩ/m
Shunt Impedance	27.9 MΩ/m *
Q	7715*
Power ATTN	0.35dB/m*
RF power needed to support 1MV/m gradient	439kW

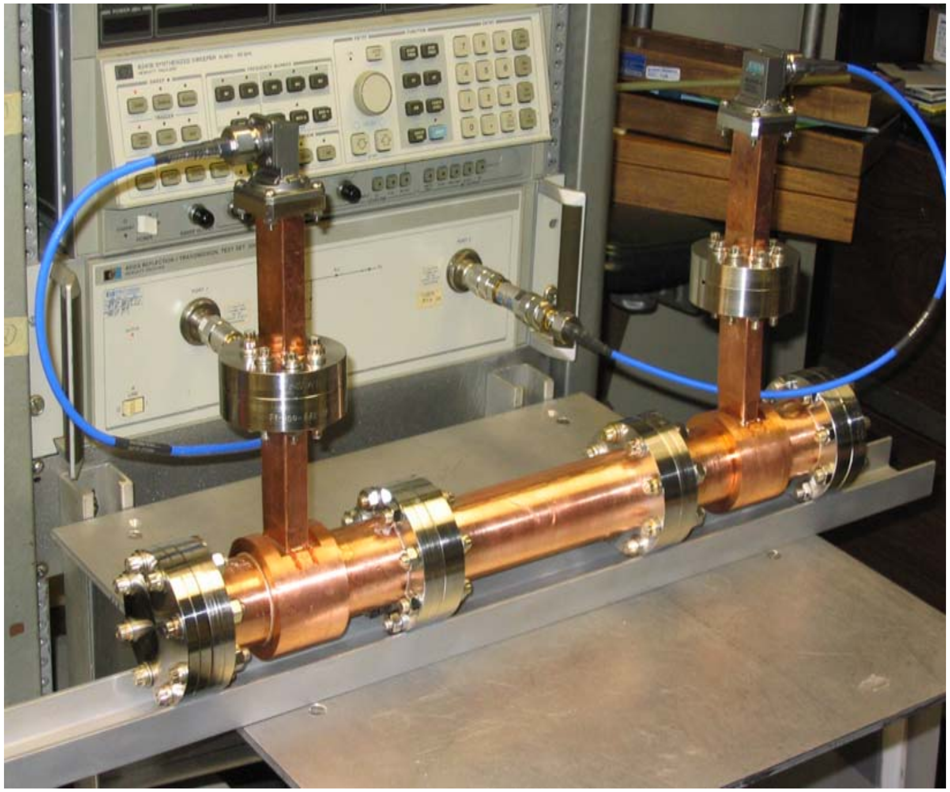
*Loss tangent of the dielectrics is $2*10^{-5}$.



High Power RF Testing of The Quartz Based DLA Structure (III)

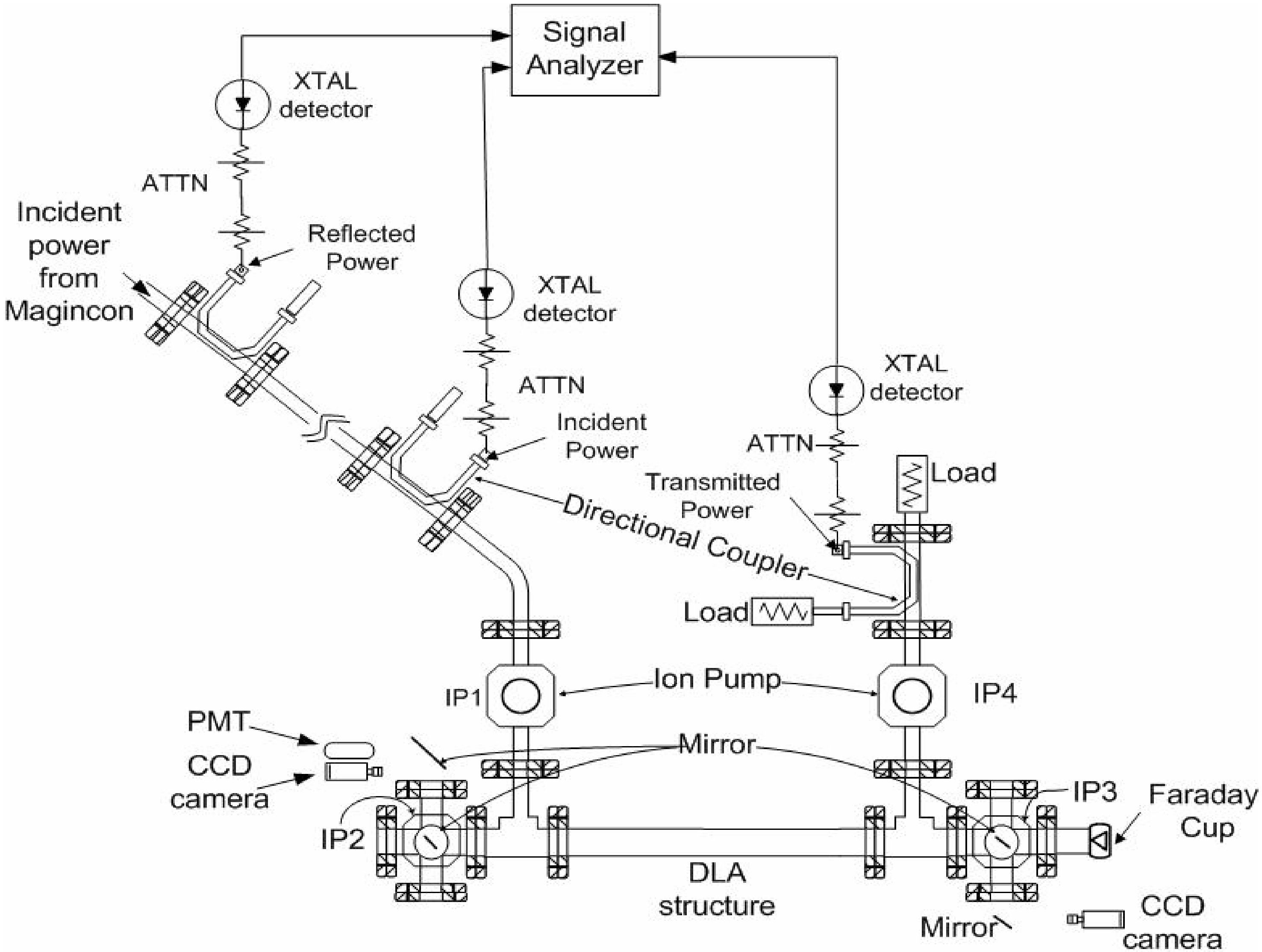
--------Bench Testing





High Power RF Testing of The Quartz Based DLA Structure (IV)

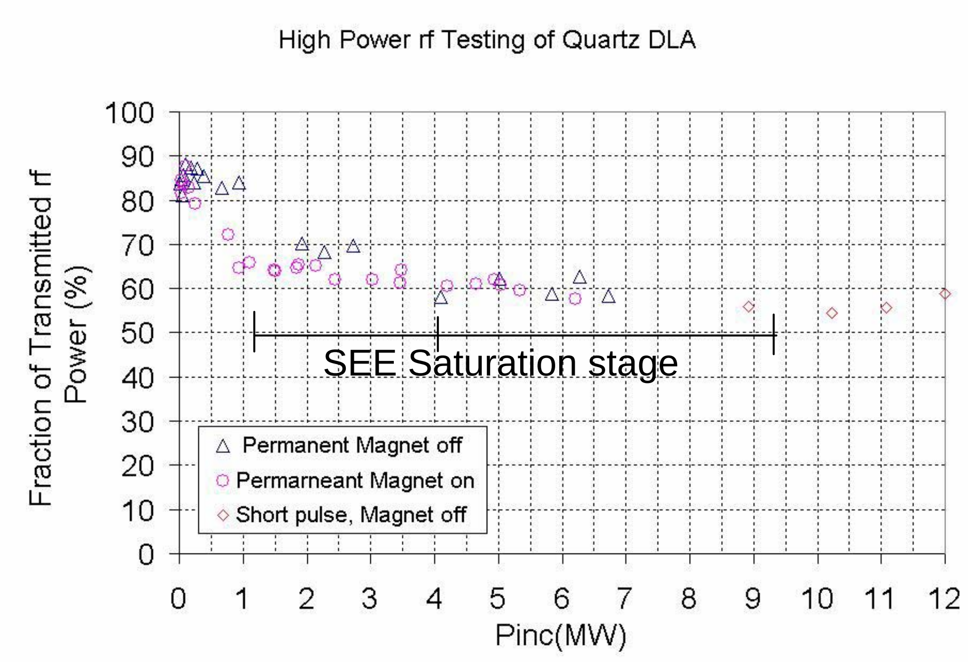
-------High Power Testing Setup at NRL



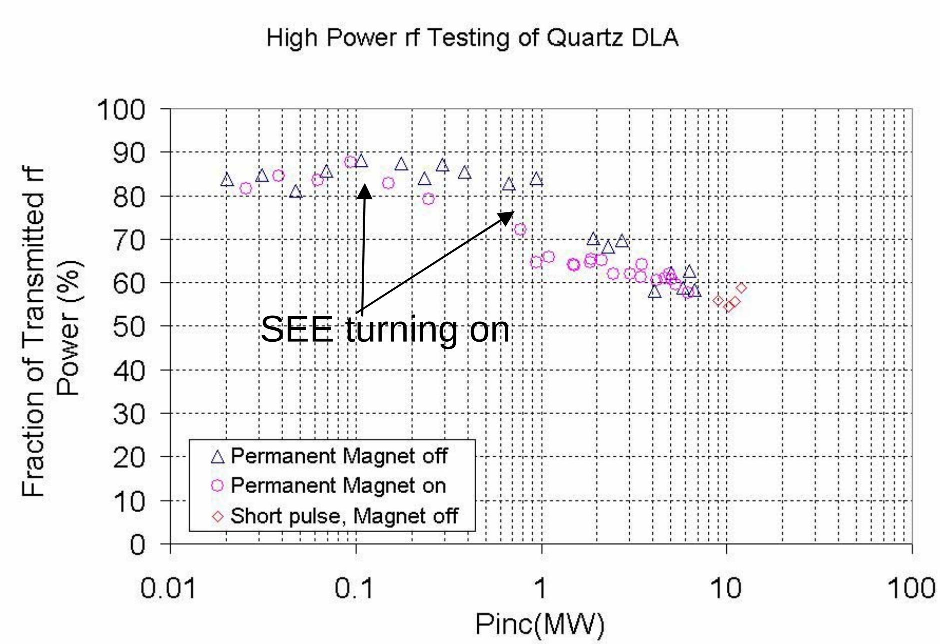
High Power RF Testing of The Quartz Based DLA Structure (V)

-------- Testing Results (i)

No breakdown up to ~5 MV/m
Large multipactor again



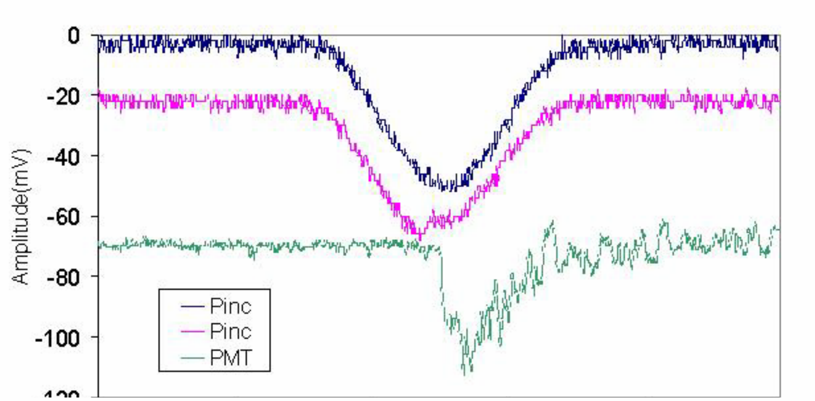
Linear scale



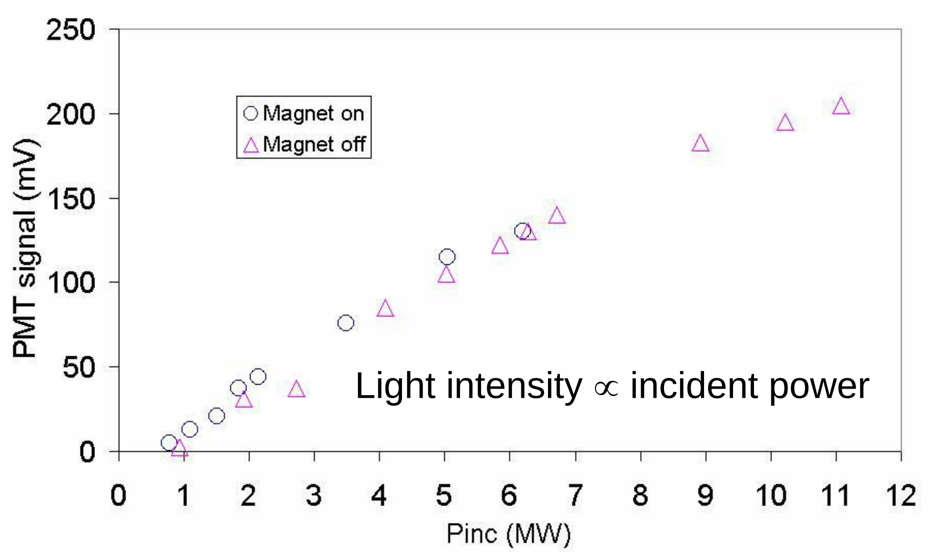
Log scale

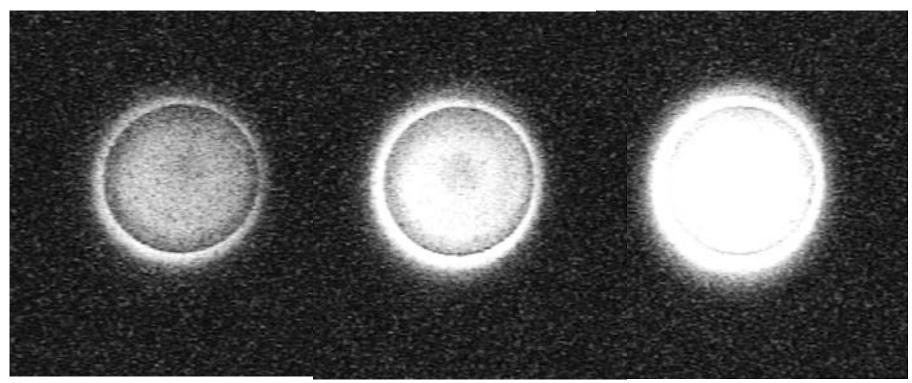
High Power RF Testing of The Quartz Based DLA Structure (VI) -------- Testing Results (ii)

Using PMT to monitor Multipactor turning on

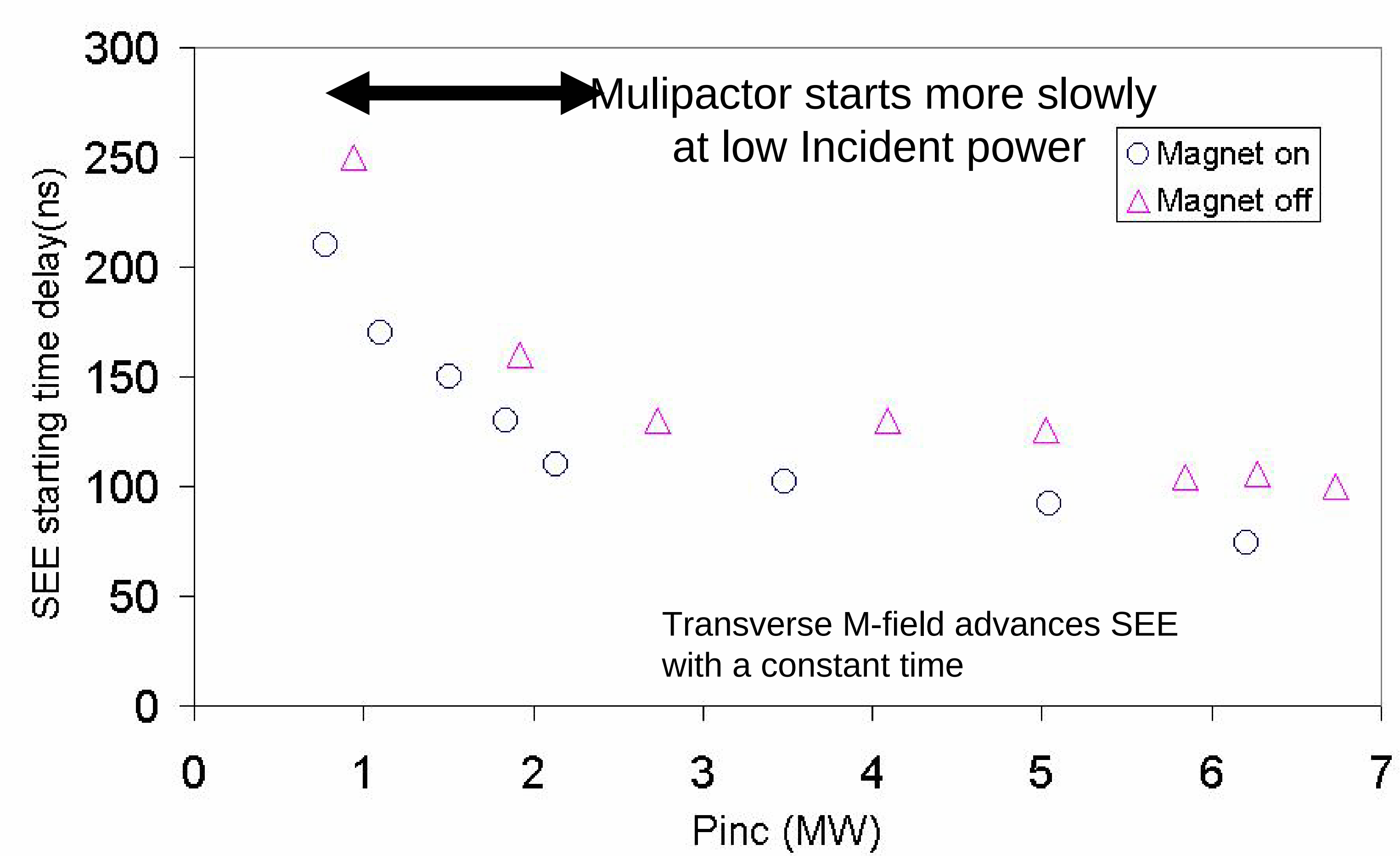


Incident rf vs. PMT signal





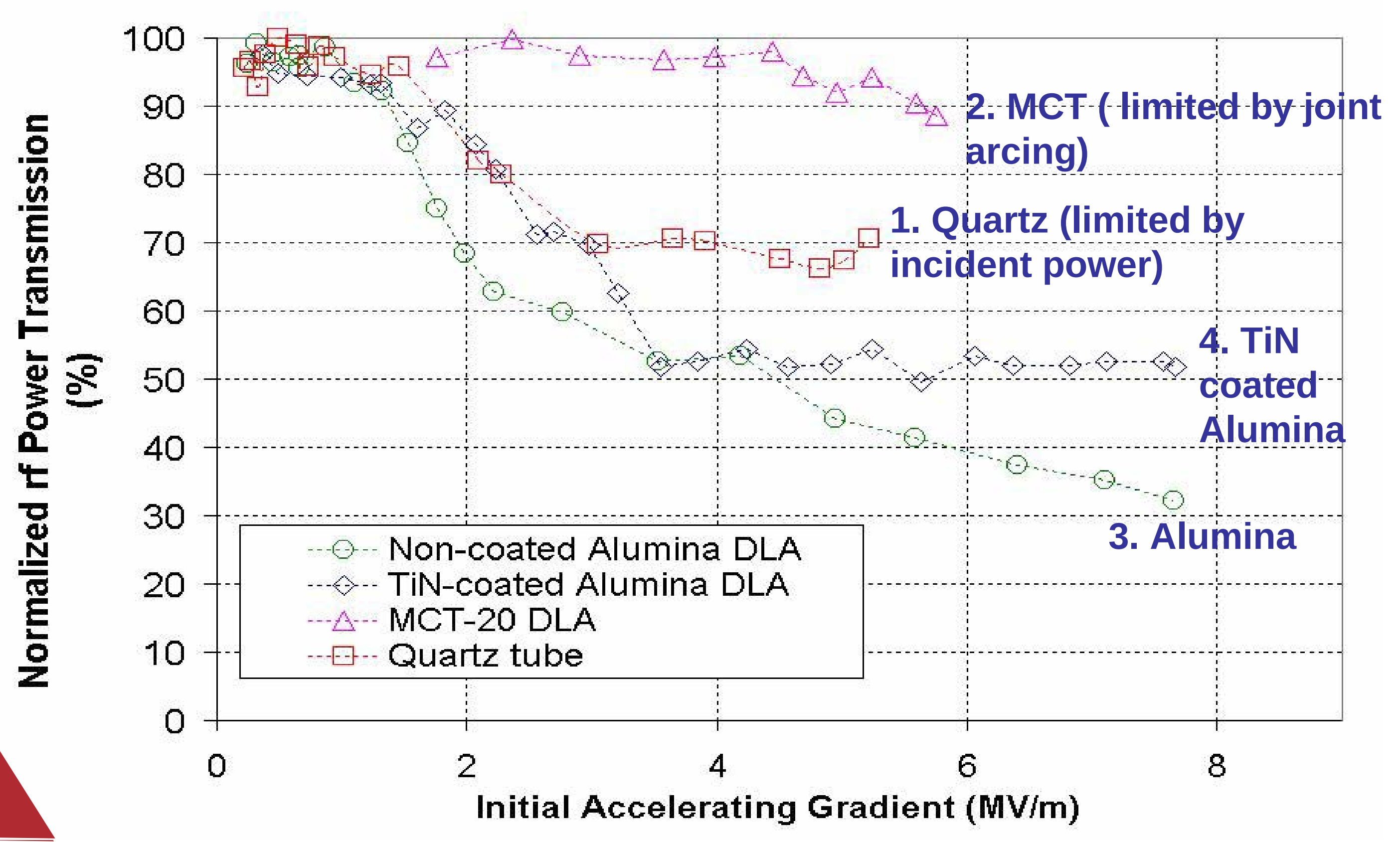
Multipactor Turn-on time

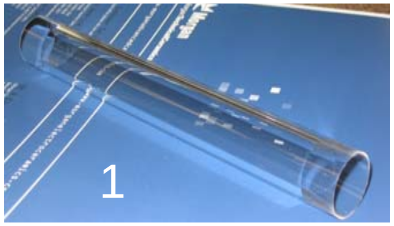


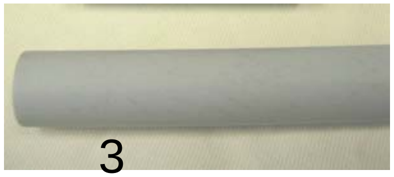
High Power RF Testing of The Quartz Based DLA Structure (VIII)

-------- Comparison

- ➢Dielectric Breakdown: Not seen in any structure
- ➢Multipactor Induced Power Loss: lower in MCT and Quartz, saturate in Quartz and Al-TiN
- ➢Joint Breakdown: >100 MV/m at joint in MCT;







High Power RF Testing of The Quartz Based DLA Structure (IX)

-------- Summary

→DLA Progress to Date

- →Four generations of couplers and structures designed and tested.
- →Four different dielectric materials tested (Alumina, Fused Quartz, MCT, TiN coated Alumina)
- →No Breakdown of the bulk dielectric observed (up to 8 MV/m)
- →Multipactoring and joint breakdown discovered; developed schemes to suppress
- →Gained fundamental understanding of the issues and developed new multipactoring theory.

→DLA Future High Power Tests

- →Joint-less DLA Structures (avoid joint breakdown)
- →Small I.D. (Reduce Multipactor)
- →Double Layer (Lower Power Attenuation)

Part II

1. The Recent High Power rf Testing of Quartz Based DLA Structure

2. Ways to Higher Gradient for DLA Structures

   - Small I.D. quartz DLA structure design: Test high gradient and multipactor power scaling

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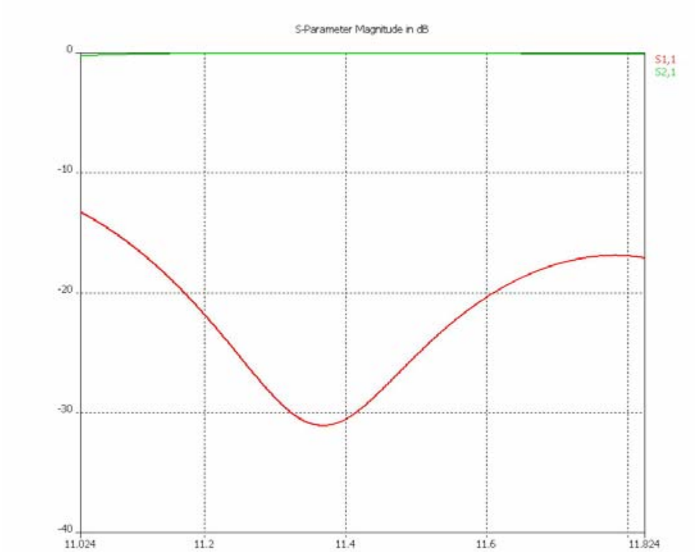
Small ID Quartz Based DLA structure design (I)

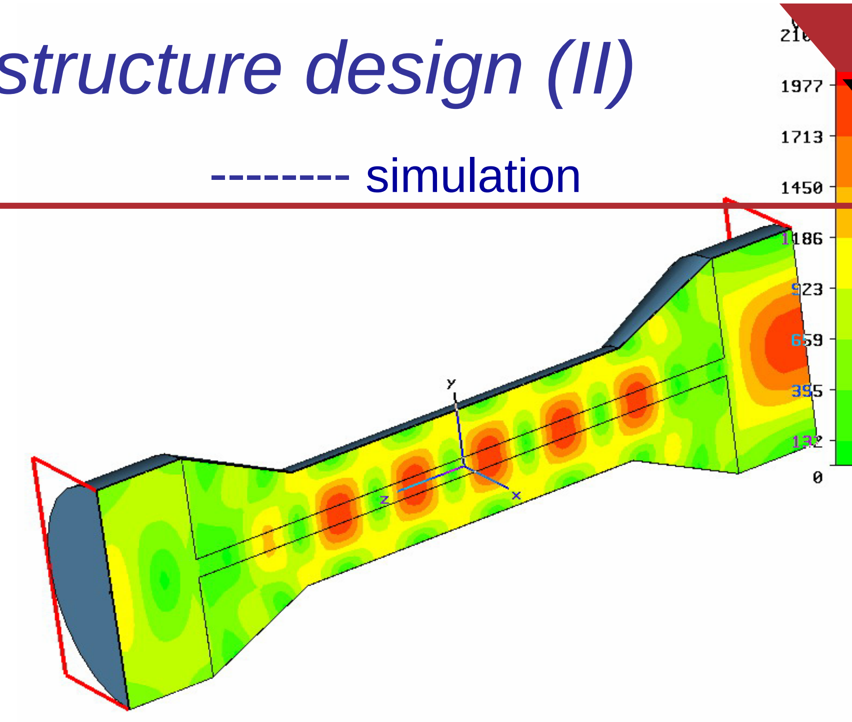
------Parameters for different loaded materials

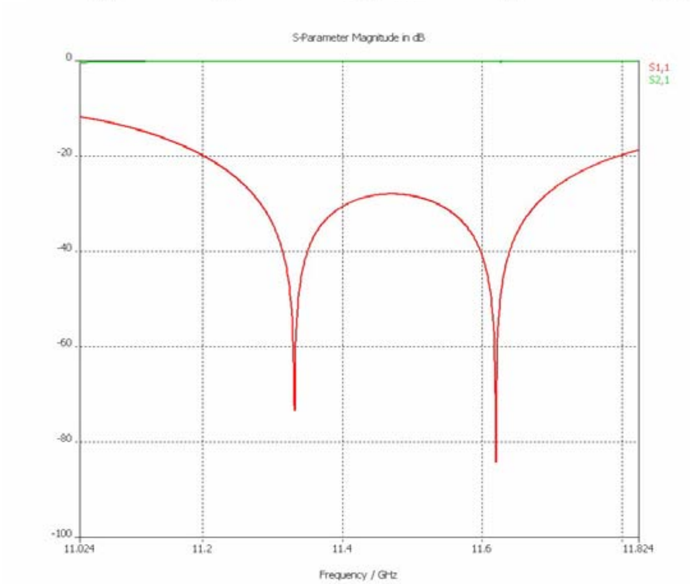
Loaded Material	dimensions	Group Velocity	Bandwidth (S11<-15dB)	Gradient per 10MW	Gradient per 100MW
Quartz (ε=3.75)	ID=2mm OD=12.52mm	0.267c	480MHz	12.3MV/m	38.9MV/m
Cordierite (ε=4.76)	ID=2mm OD=10.85mm	0.21c	350MHz	14.6MV/m	46.2MV/m
Alumina (ε=9.77)	ID=3mm OD=8.23mm	0.1c	300MHz	19.8MV/m	62.6MV/m
MCT (ε=20)	ID=3mm OD=6.42mm	0.05c	42MHz	26.5MV/m	83.8MV/m

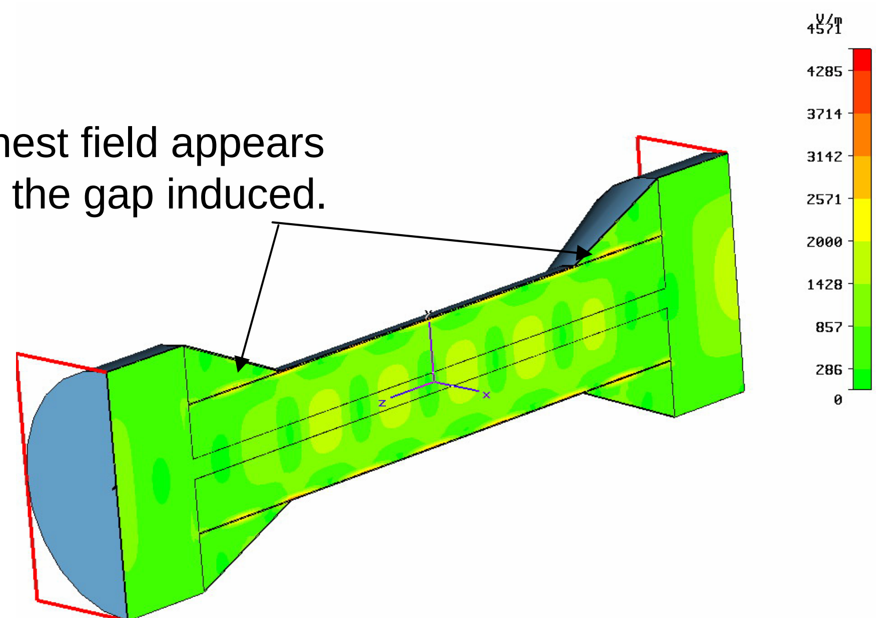
Small ID Quartz Based DLA structure design (II)

-------- simulation









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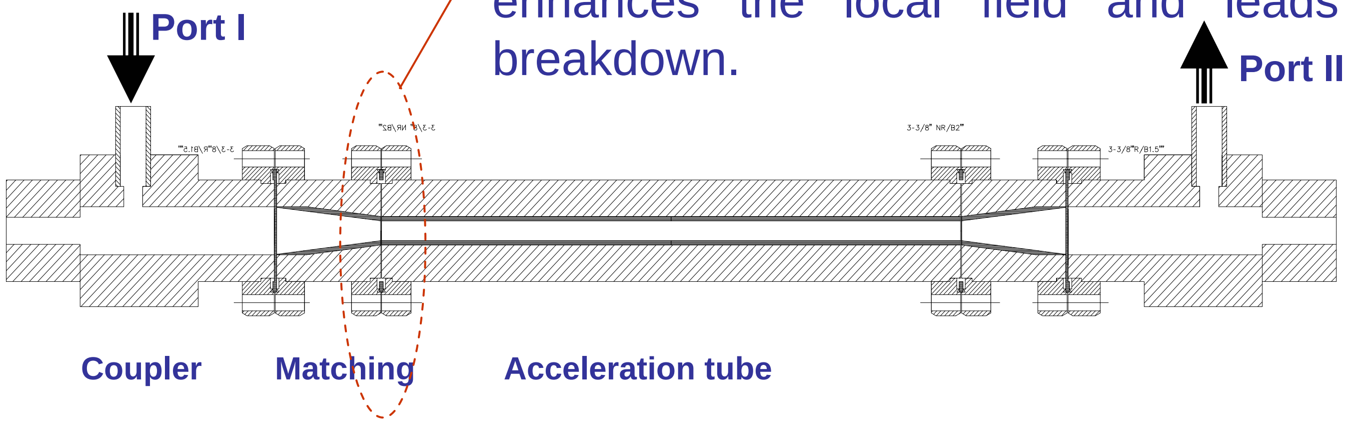
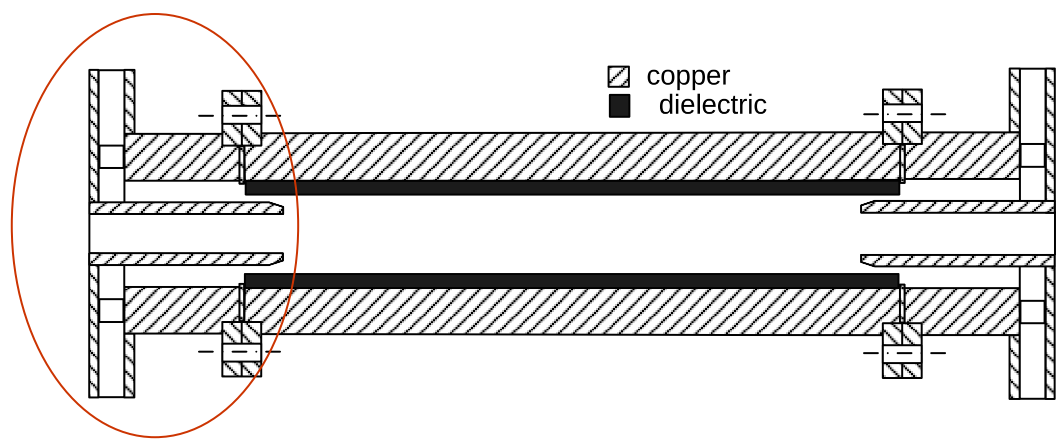
Gapless DLA structure based on the new coupler design (I)

-------- concept

Limitation of the current design----Gap at the dielectric joints (matching-accelerating sections) enhances the local field and leads to joint breakdown.



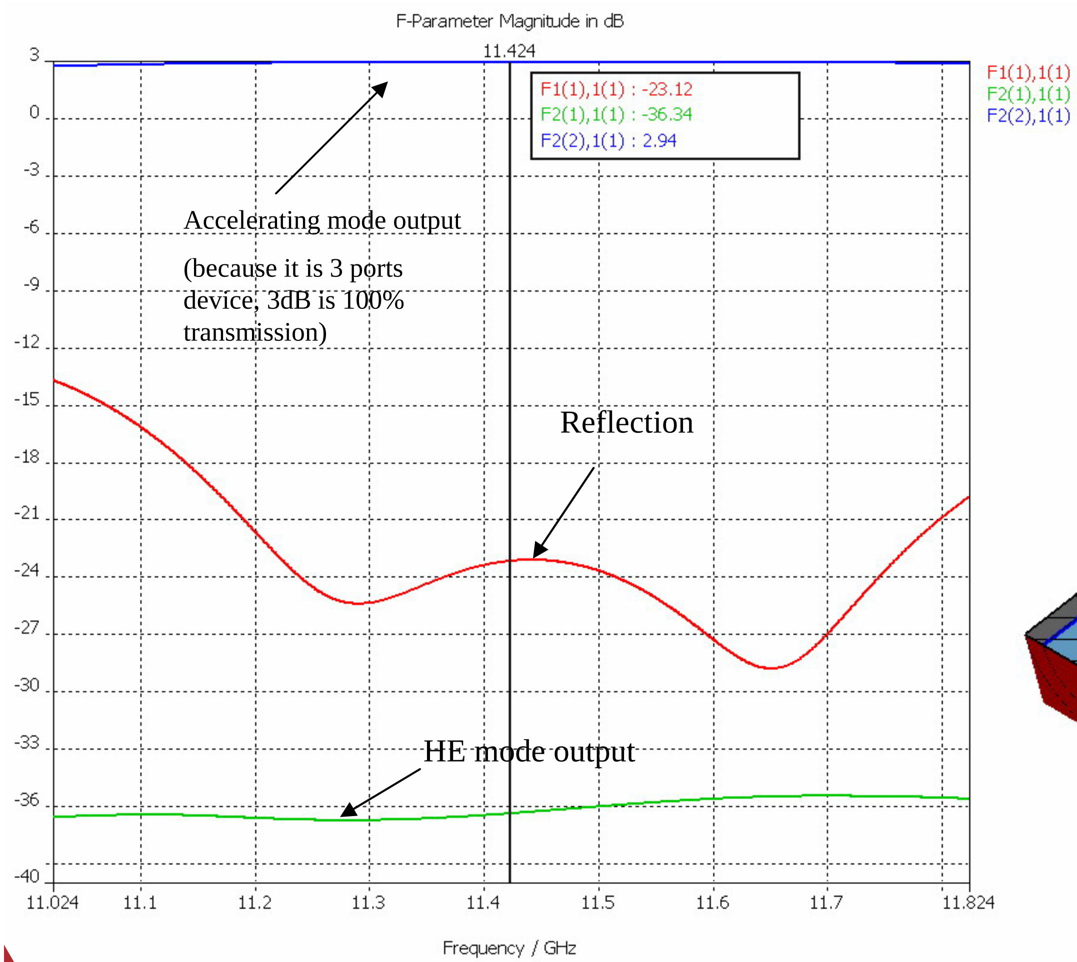
New design uses the coaxial coupler which eliminates the dielectric taper section in the current design

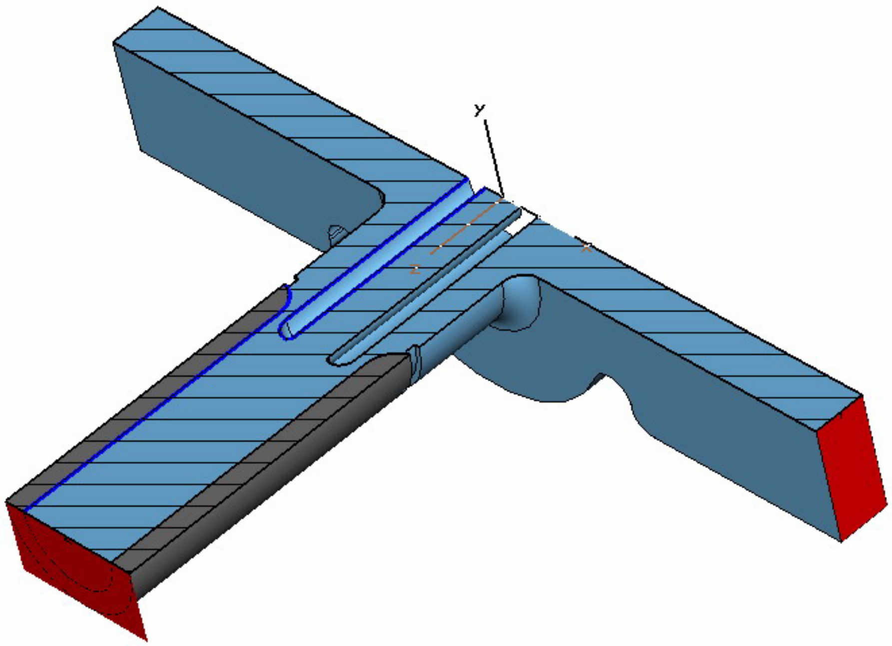


* Funded by SBIR

Gapless DLA structure based on the new coupler design (II)

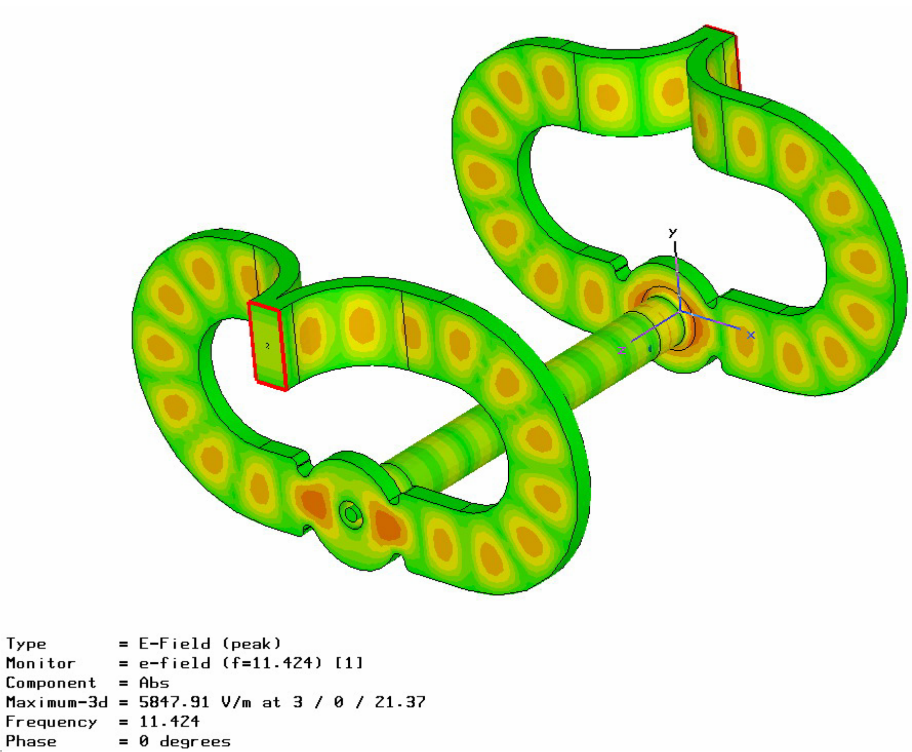
-------- coupler simulation

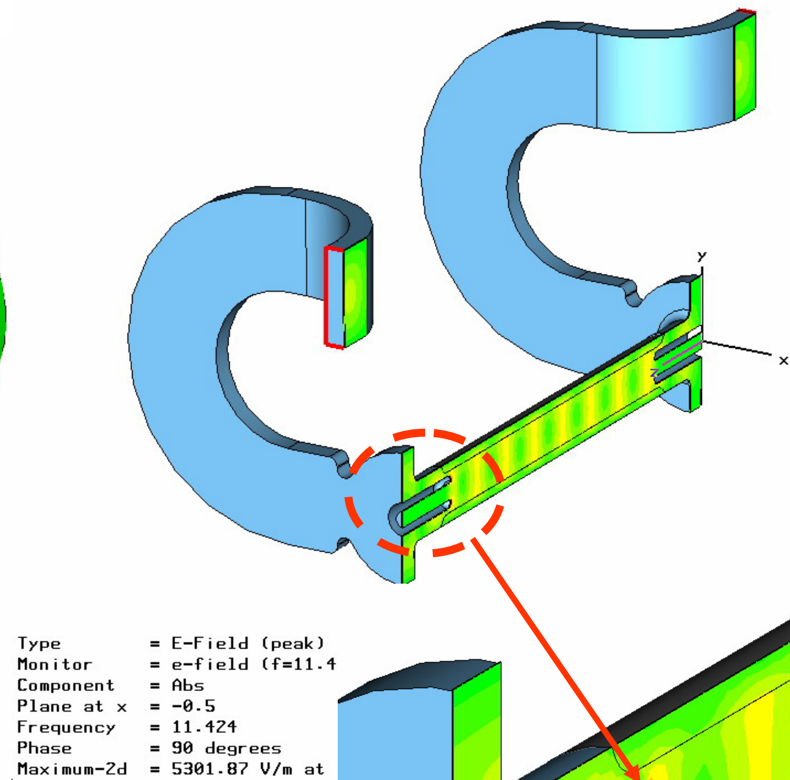


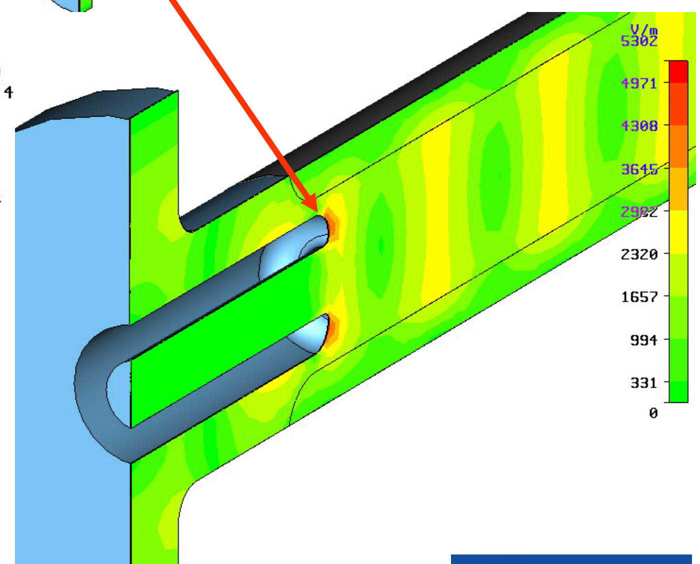


Gapless DLA structure based on the new coupler design (III)

-------- Structure simulation







- There is no dielectric gap in the structure.
- Highest E-field appears at inner conductor tip, but the field enhancement ratio has only 1.6 to the accelerating gradient.

Part II

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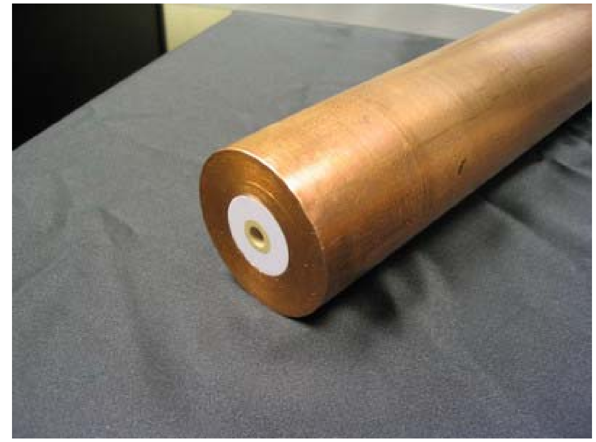
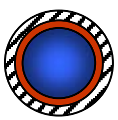
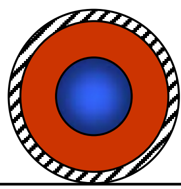
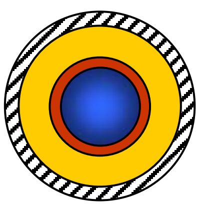
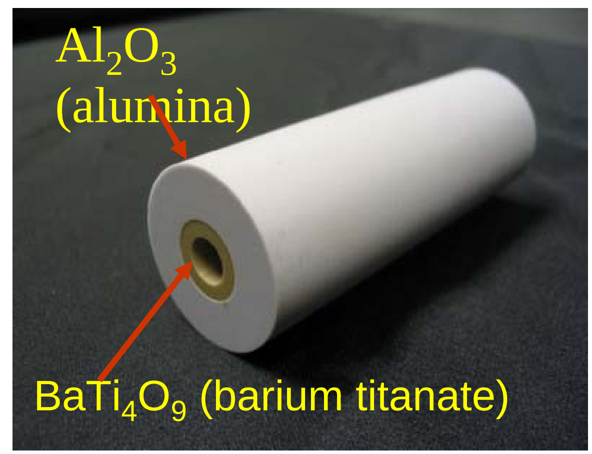
Low loss double layer DLA structure (I) -------- Concept

X-band Dual layer Dielectric-Loaded Accelerating Structure, funded by SBIR, is being developed at Euclid Techlabs, LLC in recent several months. So far, the entire targets proposed in Phase I plan have been accomplished which include fabrication of dual layer ceramic tube, simulation and fabrication of TM_{03} mode launcher and bench testing.

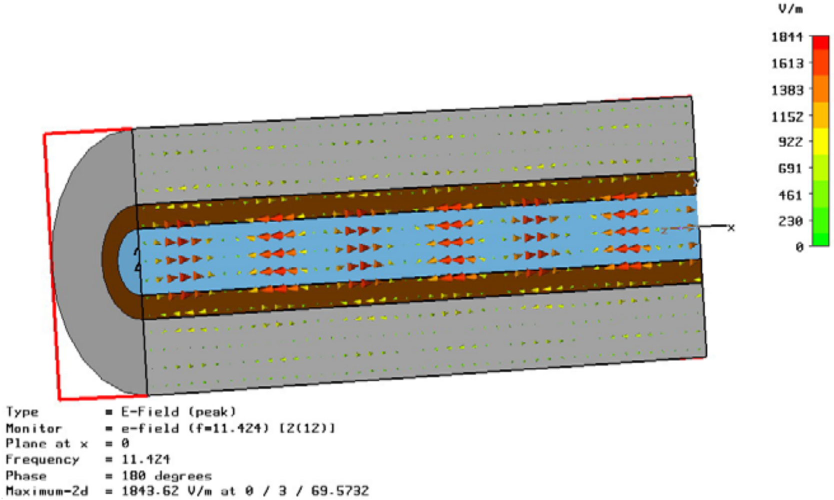


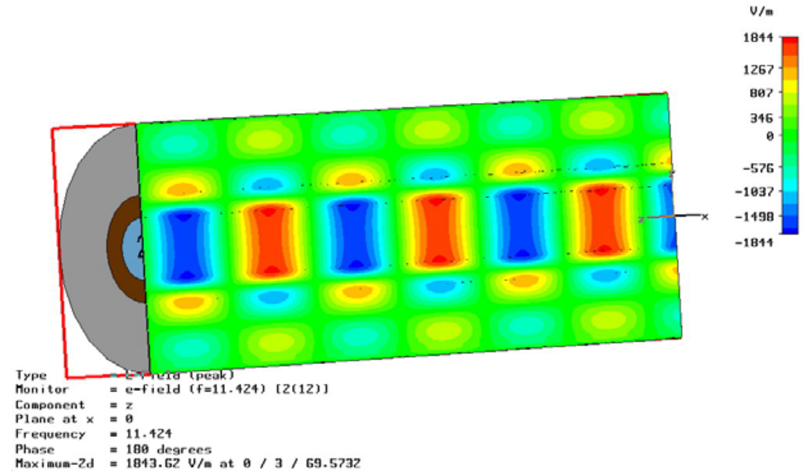
Ceramic with high permittivity (37); Ceramic with low permittivity (9.7); Air; Metal jacket	Group velocity (×c)	R (MΩ/m)	R/Q (Ω/m)	Power Attn (dB/m)
 1 layer DLA TM_{01} mode IR:3—4.13mm	3%	11.7*	1681*	-20*
 1 layer DLA TM_{03} mode IR:3—8.49mm	3%	7.4*	1553*	-7.8*
 2-layer DLA TM_{03} Mode IR:3--5.17—12.02mm	6%	14.5*	2040*	-2.3*



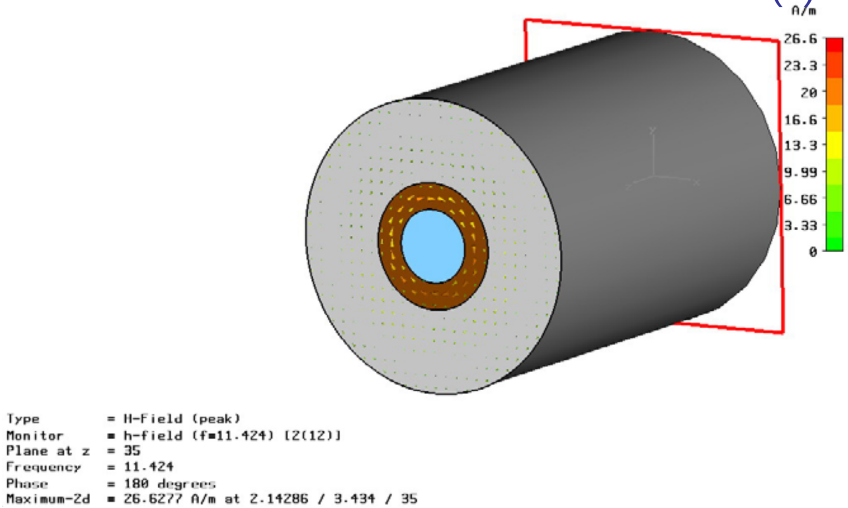
* Based on loss tangent of 10^{-4}.

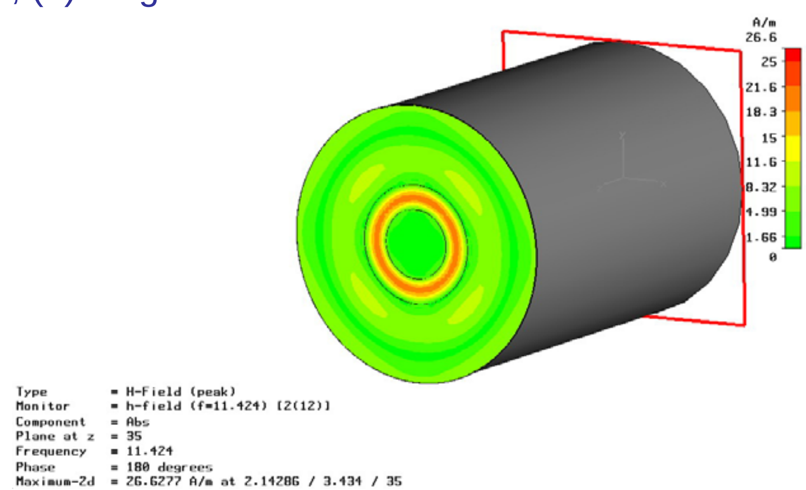
Low loss double layer DLA structure (II) -------- Field profile





Electric field of dual layer DLA structure simulated with Microwave Studio®: (a) vector plot; (b) magnitude.





Magnetic field pattern of the double layer DLA structure simulated with Microwave Studio®: (a) vector plot; (b) magnitude.

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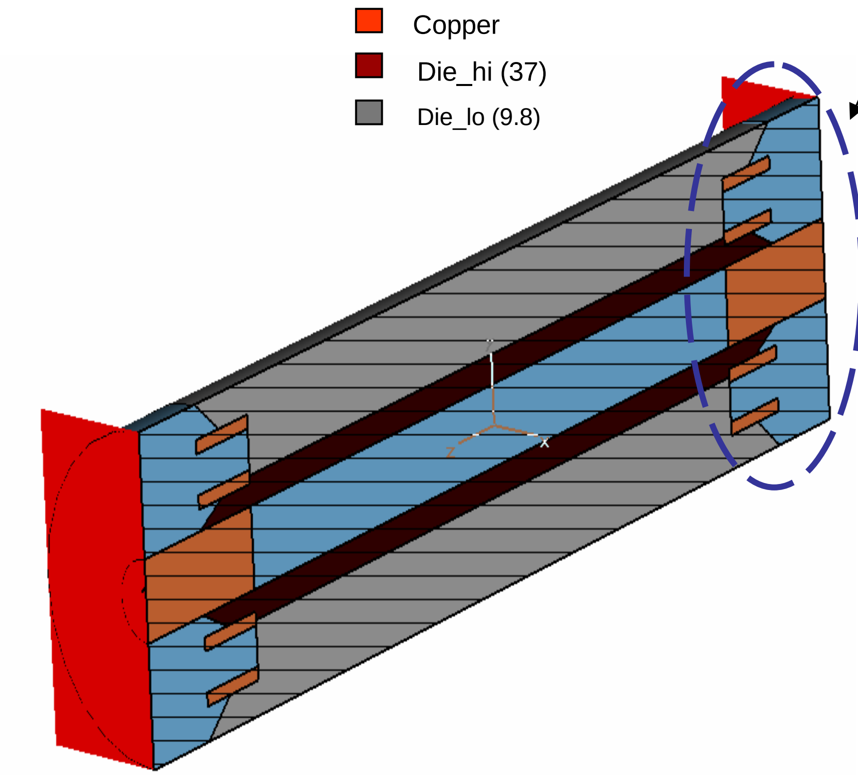
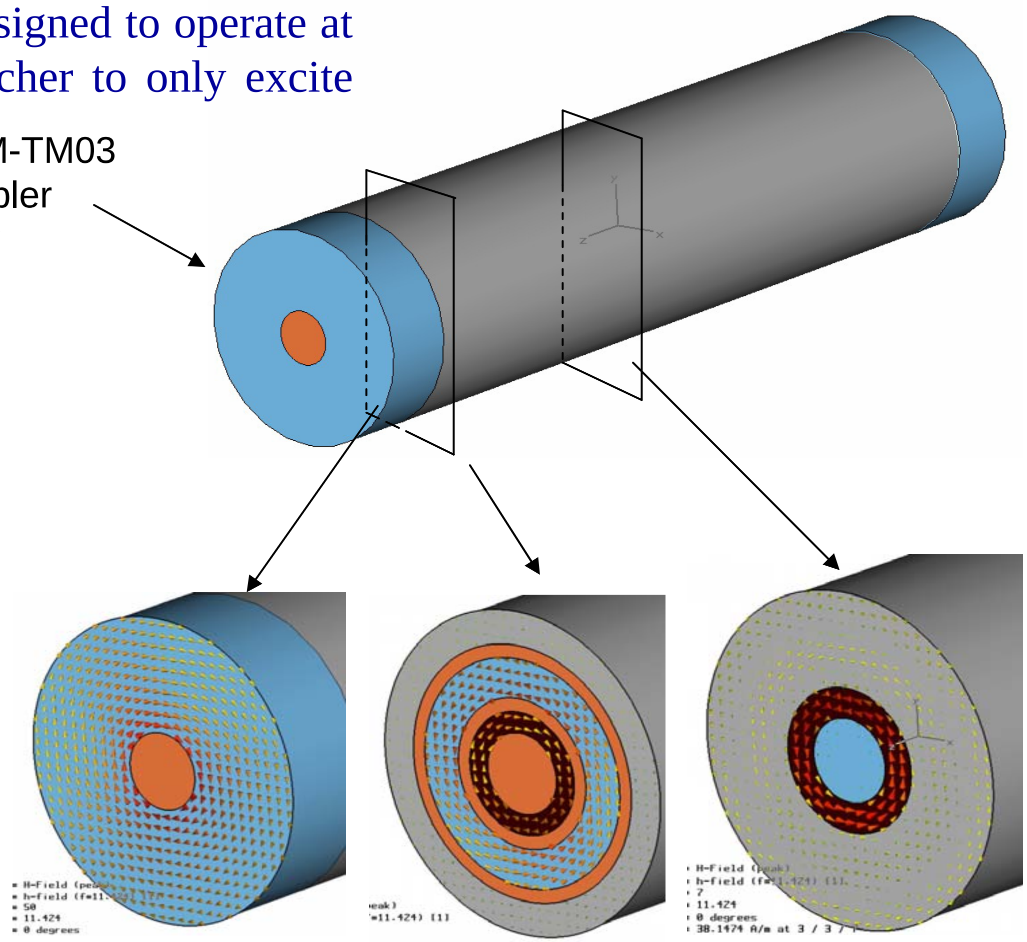
Low loss double layer DLA structure (III) ----TM_{03} Mode Launcher

Because that the dual layer DLA structure is designed to operate at TM_{03} mode, we developed a TM_{03} mode launcher to only excite TM_{03} mode in the structure.



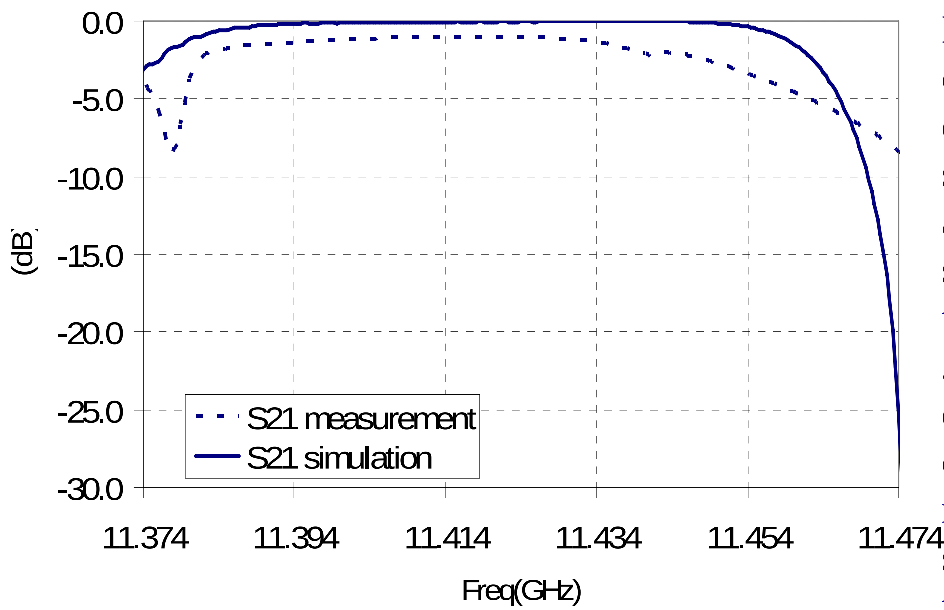


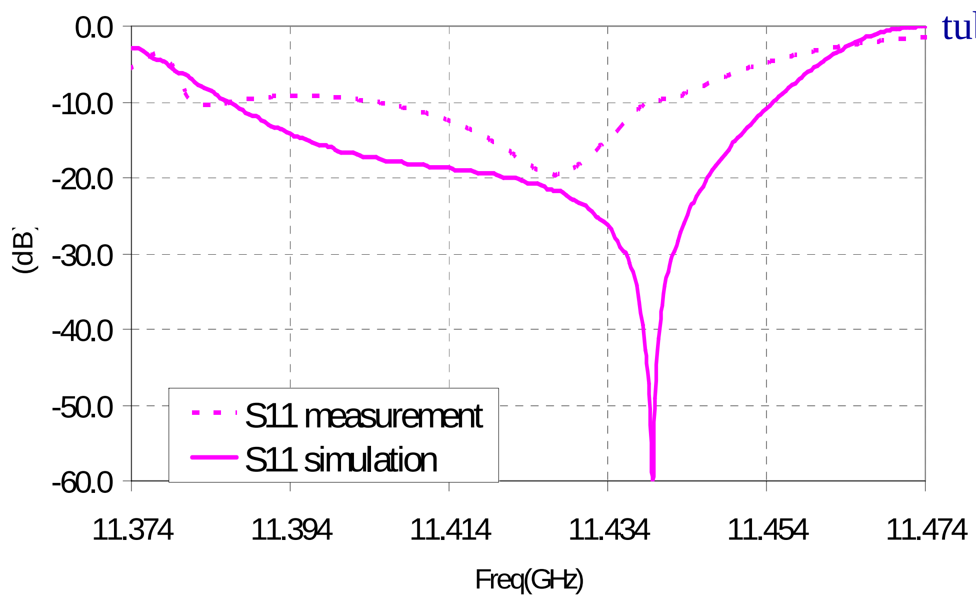
Transmission Line

Coupler

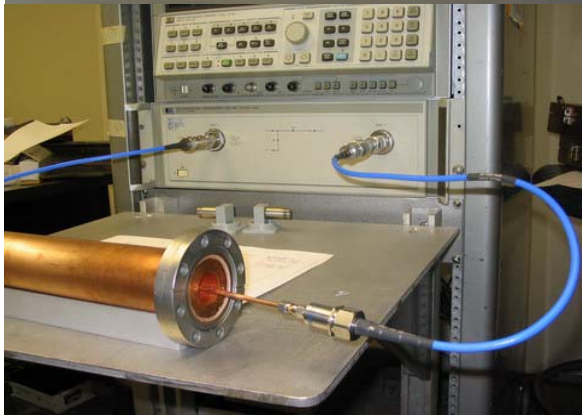
TM03 Accelerator

Low loss double layer DLA structure (IV) -------- Bench Testing





Based on the results of bench testing, the dual layer DLA structure has 4dB/m attenuation, which slightly larger than the theoretical value, 2.5dB/m. It is partly due to the larger copper loss from rough surface, and slightly higher loss tangent of ceramc tube.



Summary

- We have tested RF and multipactor behaviors of the quartz based DLA structure;12MW rf power was input without breakdown; saturation stage of the multipactor appeared at 1MW rf input; the same structure will be tested with higher rf power.

- We are moving forward with some new DLA structures design to try to achieve a higher accelerating gradient and lower RF loss.